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ENGINEERING SUPPORT AND MANUFACTURING FOR THE FABRICATION OF 60--ETC(U)
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LEVEL II

(10)

FINAL REPORT

ENGINEERING SUPPORT and MANUFACTURING

FOR

FABRICATION of 60 each TAPER SHAPED SWAGED CORES

M735

CONTRACT DAAK 10-77-C-0070

PREPARED FOR

DEPARTMENT OF THE ARMY

U.S. ARMY ARMAMENT R&D COMMAND

DOVER, NEW JERSEY 07801

PREPARED BY

TELEDYNE FIRTH STERLING

LA VERGNE, TENNESSEE 37086

DECEMBER, 1980

FINAL REPORT

ENGINEERING SUPPORT AND
MANUFACTURING FOR THE
FABRICATION OF 60 EACH TAPER
SHAPED SWAGED CORES

CONTRACT DAAK10-77-C-0070

PREPARED FOR:

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DECEMBER 1980
Revision 2

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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PENETRATORS

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The development of a technique and determination of feasibility of producing the M735 Tungsten Alloy Core to a ballistically and mechanically acceptable standard by taper swaging a near-net shape sintered blank. Description of manufacturing techniques of pressing, sintering and swaging employed. Special emphasis on techniques for taper swaging using progressive opening of the die segments, a special die configuration and a control system used as selected method of reaching desired results. Process offers a possible cost reduction by reducing the starting weight of alloy powder by some 40%.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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I. SUMMARY

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SUMMARY

This program has demonstrated the feasibility of producing the M735 Tungsten Alloy Core to a ballistically and mechanically acceptable standard by taper swaging a near-net shape sintered blank.

Techniques for pressing, sintering, heat treatment and machining of tapered preforms have been confirmed. A technique for taper swaging using progressive opening of the die segments, a special die configuration and a control system were successfully developed and applied.

The process offers a cost reduction by reducing the starting weight of alloy powder needed by some 40%.

A limitation of the process is the increased mismatch between the die and the part as the dies progress along the taper. There is a resultant increase in the amount of redundant work in the material and a change in residual stress levels compared to the straight bar swage process.

Reduction of data obtained in the swage process showed that the desired pattern of cold work was not achieved in all groups.

Five ballistic groups were manufactured, and were tested after assembly, one group met the acceptance criteria for the NATO Heavy Triple Target Array.

II. INTRODUCTION

TELEDYNE FIRTH STERLING

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TAPER SHAPED SWAGED CORES
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INTRODUCTION

The M735 105MM A.P.F.S.D.S. Subprojectile contains a high density Tungsten Alloy Core weighing 2.2Kg., shaped like an elongated tear drop. The core requires cold working to attain the penetration characteristics desired.

Techniques employed previously to experimentally produce this item from a near-net shape sintered blank included upset-forging, extrusion and swage in the maraging steel sheath used for final assembly. All were found to be ballistically inferior to the rotary swaged straight bars, machined to the final configuration.

The technique of straight bar swaging presently used for mass production of the item, requires an input weight of about 7.7Kg. of Tungsten Alloy for a final component weighing 2.2Kg. Extremely poor material utilization.

Because of the potential savings possible in material and processing costs to be achieved by starting with a nominal 4.5Kg. tapered blank, it was proposed to investigate taper swaging of such a tapered blank.

This contract covers development of a process whereby the die segments move in a radial direction as swaging proceeds at a rate to give a uniform or controlled gradient of reduction in area as the tapered blank is fed into the dies.

III. MANUFACTURING TECHNIQUES

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MANUFACTURING TECHNIQUES

PRESSING

Blended alloy powder is loaded into formed thin wall containers of polyurethane having a taper internal shape and supported by an outer epoxy-fiberglass member. The assembly is then jolted, after which time a polyurethane closure is installed to secure the container prior to the blank being compressed to 30,000 PSI in a cold isostatic press.

For a production environment, the fiberglass support tube is envisioned to be changed to a metallic construction to survive the forces applied during the jolting operation.

Breakage of the pressed compact typically about 3 to 4 inches from the small diameter end may occur during the pressing operation. It is assumed that this occurence is caused by tensile stresses on the part during the depressurization as the bag returns to its original dimensions while still in contact with the component. Orientation within the press (big end down is preferred) as well as wall thickness (thinner is better) and hardness of the polyurethane container could be optimized to further improve the yield.

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MANUFACTURING TECHNIQUES

SINTERING

The sintering of near-net shape tapered components is advantageous compared to the present heavier cylindrical billet.

Furnace throughput is improved by increased loading density of components. Operating costs for this process are, in part, related to weight sintered so there is a cost savings on utilities and consumables, such as protective atmosphere (Hydrogen) and refractory support items.

The adverse effect of part mass on mechanical properties achieved is well known in the industry. Thus, the reduced blank weight gives improved mechanical properties in the sintered blank particularly at the smaller diameter or tail end of the part. This is an improvement over the lower properties normally found in the tail end of long bars sintered in stoker type furnaces.

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SWAGING

There are two basic approaches to the taper swaging of this component:

(1) Feeding a tapered component into long tapered dies,

(2) Controlled radial movement of the dies while advancing the part.

We at Teledyne Firth Sterling chose the latter system because of the lower loads inherent in progressive swaging and because of the availability of a variable die opening feature on an in-house Fellows 500 Ton Capacity Rotary Swage.

Machine loads for the tapered die approach on the large end of the penetrator, using say a four inch die contact length, have been calculated to exceed 1000 tons. While a small number of parts could be prepared in this manner, severe machine damage is possible from fatigue failure of highly stressed machine components in a continuous production environment.

By using a progressive die movement technique, loads are greatly reduced compared to that experienced in the normal production of the straight bar. This can be attributed to the more open die configuration

which results as the die form (which must be of a radius greater than or equal to the maximum part diameter) contacts the lesser diameter down the taper, giving a small die contact area.

There are some inherent difficulties, however. The motions of the die blocks and feed mechanism must be carefully synchronized to control the extent of cold work introduced into the material.

The increasing mismatch between the die and component form away from the largest part diameter changes the swaging load and, in turn, the machine deflection under load thus an additional variable is introduced into the geometric relationship between die form and the part.

It was decided that the close control needed could not be achieved with conventional machine settings but rather than precise continuous measurement by means of L.V.D.T.'s of axial infeed rate and exit rate from the dies should be used to compute the degree of cold working actually being achieved on a real time basis. This would give in its simplest form indications for manual adjustment of rate valves which control die opening and eventually through a servo loop allow direct, continuous control of the swaging process.

Manipulation of the output from the L.V.D.T.'s by microprocessors was intended. Initially the output signals were recorded by a mobile data unit from ARRADCOM; this recorded data showed that such a system was feasibile. At this stage of the work it was decided to change from microprocessors to the in-house PDP11/34 Minicomputer. This allowed sampling computation and recording of each element motion at the rate of 50 times per second. The work was limited to recording such data and reducing this to graphical form for Ballistic Groups 4 and 5. This system would readily handle computation, smoothing and generation of output signals for machine control in a production situtation.

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DIE DESIGN

For taper swaging of blanks using a die retraction technique certain geometric problems arise.

In the swaging of relatively brittle materials, a close match between the throat radius of the die and the finished part radius is preferred; this is referred to as "low overgrind". Overgrind is defined as the percentage difference between the radius within the die and that of the formed part and is typically in the range of 3-5% for high density Tungsten alloys.

Of course, it is not possible to match a constantly changing radius as occurs in this instance and thus overgrind increases towards the smaller part radius.

The technique employed here utilizes a scalloped die having a 0.495 inch radius projected into a .659 inch radius with the blends polished. This allows for a good match at the 0.9 inch diameter with the four segments of .495 inch die radius as wellas at the 1.28 inch diameter part with eight segments of .659 inch radius.

The higher center to outside mechanical property gradient found can be attributed primarily to the higher overgrind condition or mismatch between die and part radius compared to the close fit conditions obtained for swaging a parallel bar.

DIE DESIGN (cont.)

No surface cracking or center burst conditions in components have been noted in this study, indicating that the die design may be considered successful.

IV. DISCUSSION

TELEDYNE FIRTH STERLING

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TAPER SHAPED SWAGED CORES
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DISCUSSION

Comment on the actual manufacturing techniques has been covered in earlier sections of this report except in the key area of swage control and its relationship to resultant material properties.

Reductions in area to 13% which is typical for the production process were achieved at the various diameters along the taper without causing cracking or center burst conditions. This capability is ascribed to the scalloped die profile developed and used. This design is included as a sketch in the Appendix to this report.

With that achievement taken together with a good sintered product and an adequate rotary swage it only remained to demonstrate consistent control and a correct work profile in the components.

It has been stated earlier that close synchronization of the motions of the part in relation to the dies and the die opening is essential.

The die motion on the Fellows Multiflo machine is controlled by movement of four (4) wedges driven by a hydraulic motor and this is governed by electrohydraulic valves with adjustable rate control.

DISCUSSION (cont.)

Routinely control of the amount of cold-work by swaging can be made by simple measurement of part diameters before and after a pass through the machine. In the case of the present study on tapered sections measurement of diameter is insufficient. Reduction in area of course gives a corresponding increase in length and, thus, a summation of all the work done is apparent in a measured increase in length after swaging. Unfortunately, this by itself does not guarantee that the pattern of cold work is that which was intended.

A main thrust of this work was to investigate the possibility to determine an instantaneous reading of the reduction in area during the swaging process and to use the derived indications to control the machine settings to give the desired result.

The system chosen consisted of linear variable displacement transducers, measuring the infeed motion of the part into the dies, the outgoing displacement of the part from the dies and in addition the die setting in a radial direction.

Considerable effort was needed to achieve local linearity in the 20 inch stroke LVDT's necessary to accomodate machine movements. This was arranged by the use of multiple correction factors stored on disc in a PDP11/34 computer and retrieved by software as called for by the output signal from the LVDT.

DISCUSSION (cont.)

The extent to which the output motion is exceeding the infeed rate of the part can be used to calculate and monitor the rate of cold work being achieved.

A series of recordings were made initially using an F.M. tape recorder in a mobile data van from ARRADCOM and in the case of Ballistic Groups 4 and 5 directly into the PDP11/34. Graphical representations of the desired motions and derivative functions processed in this case after completion of the swage pass are included in the Appendix of this report.

Study of this data indicates that we did not have optimum machine settings. In general we caused more cold work that intended towards the "tail" of the penetrator and less toward the head or striking end of the part. There was too a zone of reduced working near the center of the bar.

Whilst these conditions probably detracted from the desired property distribution it is considered to be a positive indication of the possibility to use such a system of measurement and data reduction to control a production taper swage process with additional software and servo drive control to the die elements.

Mechanical properties were determined in non-standard positions compared to those required in plain bars. Therefore, direct comparison of data is not possible. It can be said, however, that viewed against the production data base adequate properties for good penetration can be achieved.

DISCUSSION (cont.)

At the time of this report Ballistic Test Reports have not been received from Aberdeen Proving Grounds and comparative analysis of test data in this report with ballistic results is not possible.

V. CONCLUSIONS AND RECOMMENDATIONS

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TAPER SHAPED SWAGED CORES
CONTRACT DAAK10-77-C-0070

CONCLUSIONS AND RECOMMENDATIONS

This work has demonstrated a method of rotary swaging a tapered high density Tungsten alloy blank using a controlled radial opening of the dies as the part infeeds to the machine.

A die profile design was developed and proved capable of working the 97% Tungsten alloy without causing material damage over a range of diameters from 0.9 inch to 1.28 inch.

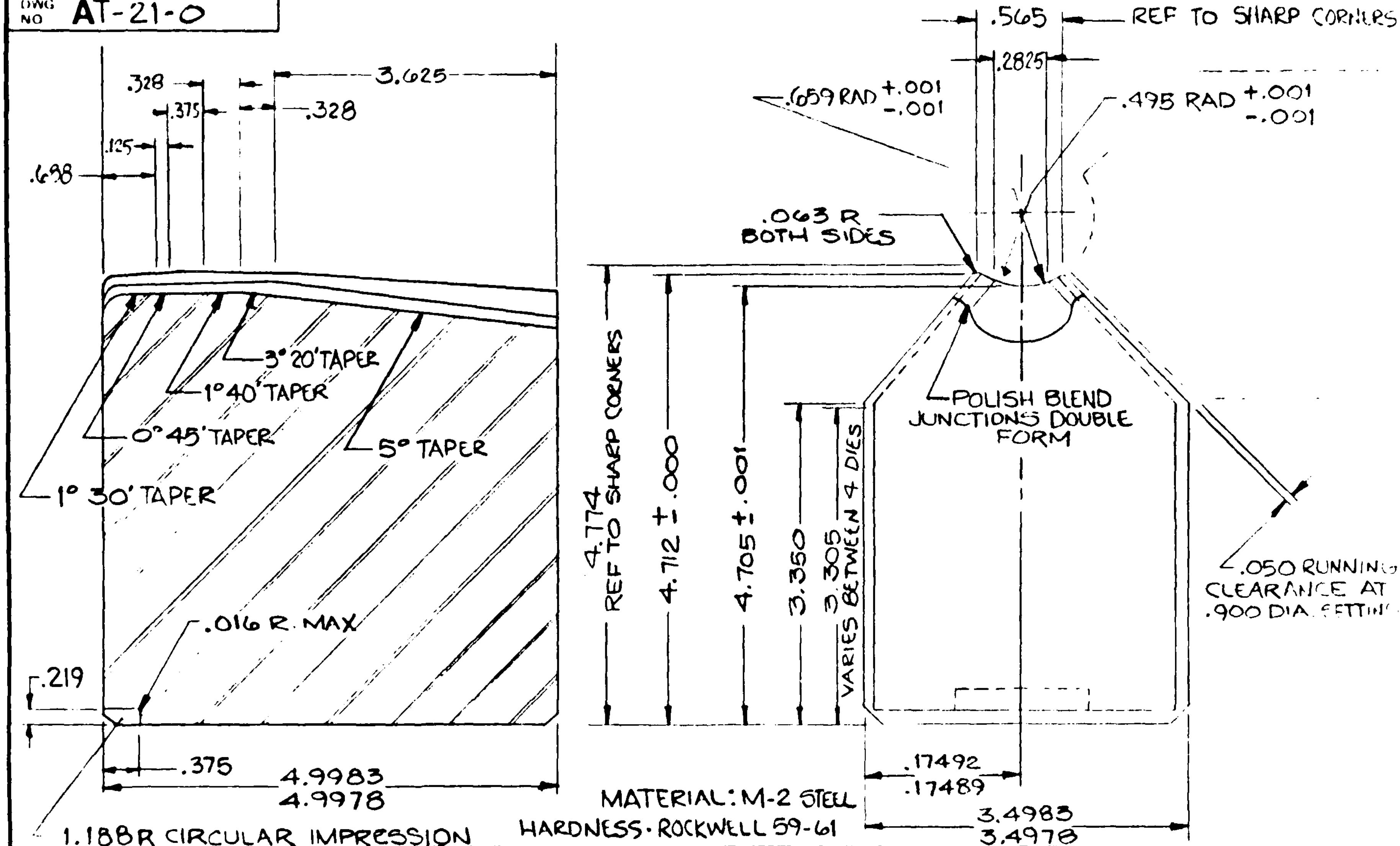
Instrumentation to determine the relative motions of infeed and output together with die setting was developed and the data handled on a real time basis was used to analyze the operation and is considered to be capable of providing the necessary control for consistent results.

The seventy-five plus penetrators made with various patterns of cold work were considered to be satisfactory from a manufacturing point of view. Further components and firing trials would be needed for process approval.

In view of the limited production of the M735 round intended it is not recommended to pursue this work further at this time.

VI. APPENDIX

DWG NO AT-21-0



TOLERANCE	
FRACTIONAL DIMENSIONS	1/32
DECIMAL DIMENSIONS	.010
ANGULAR DIMENSIONS	1
UNLESS OTHERWISE SPECIFIED	

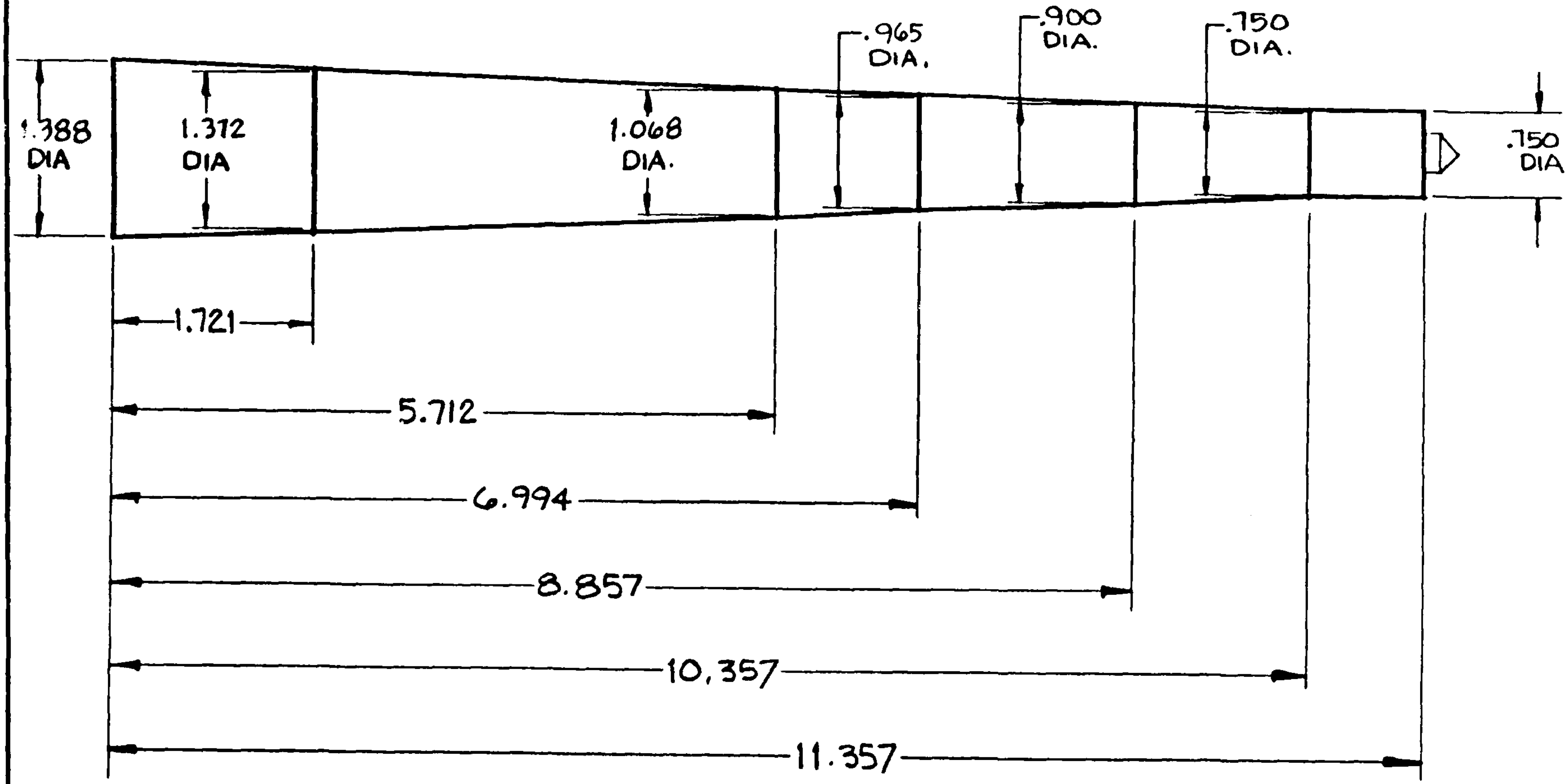
REVISIONS

SYM.	DESCRIPTION	DATE	BY

TELEDYNE FIRTH STERLING

TITLE TAPER SWAGE DIE
1 SET - CONSISTS OF 4 IDENTICAL BLKS
PROJ AUTH
W.O. No
DIVISION NASH
DEPT SWAGE
DRAWN BY WAM
DATE 8-20-80
CHECKED BY
SCALE NOT TO SCALE
APPROVED BY
DWG NO AT-21-0

DWG NO AT-22-O



TOLERANCE	
FRACTIONAL DIMENSIONS	± 1/32
DECIMAL DIMENSIONS	± .010
ANGULAR DIMENSIONS	± 1°
UNLESS OTHERWISE SPECIFIED	

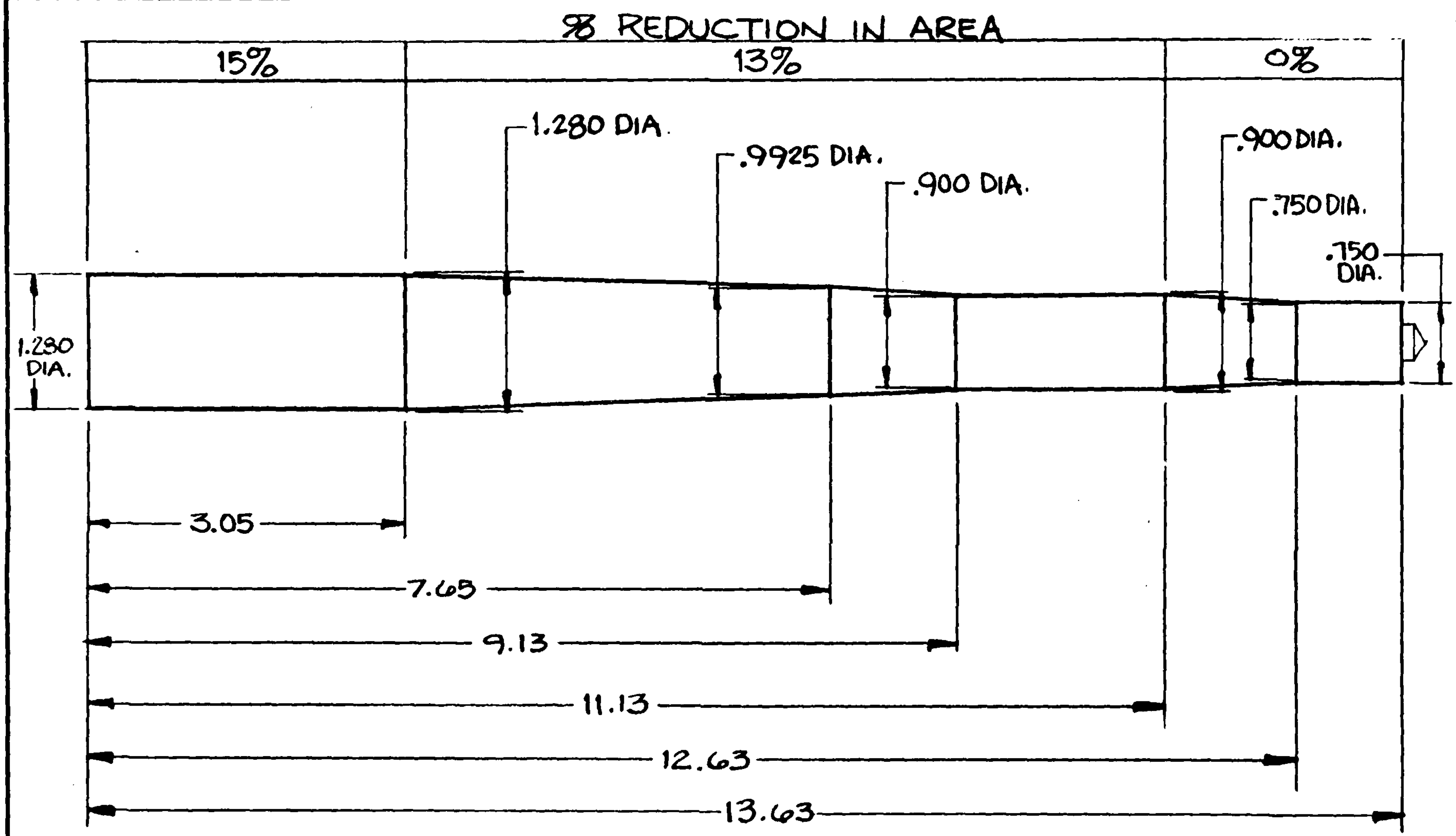
REVISIONS

SYM.	DESCRIPTION	DATE	BY

TELEDYNE FIRTH STERLING

TITLE TURNED BLANK	PROJ AUTH W.O. No
DIVISION NASH DRAWN BY WAM CHECKED BY APPROVED BY	DEPT MACH DATE 8-20-80 SCALE NOT TO SCALE DWG NO AT-22-O

DWG. NO AT-23-0



TOLERANCE	
FRACTIONAL DIMENSIONS	± 1/32
DECIMAL DIMENSIONS	± .010
ANGULAR DIMENSIONS	± 1°
UNLESS OTHERWISE SPECIFIED	

REVISIONS

SYM.	DESCRIPTION	DATE	BY

TELEDYNE FIRTH STERLING

TITLE SWAGED BLANK

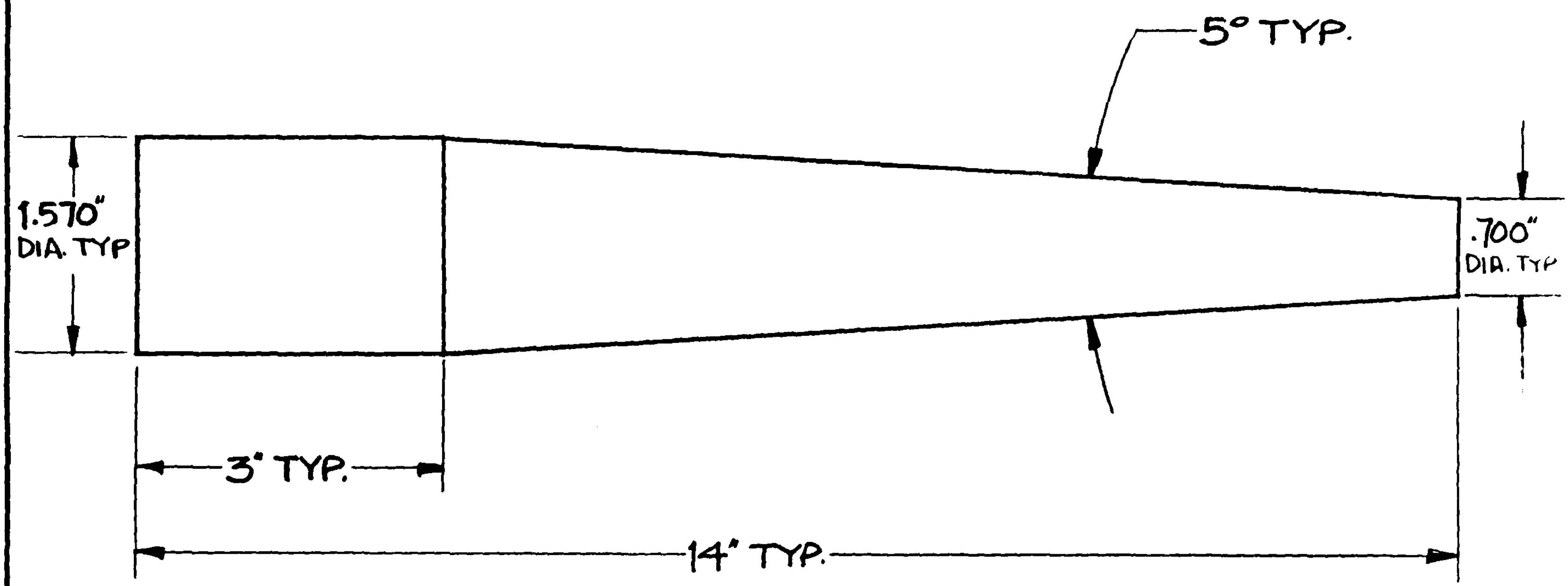
PROJ AUTH
WO No

DIVISION NASH
DRAWN BY WAM
CHECKED BY
APPROVED BY

DEPT. SWAGE
DATE 8-20-80
SCALE NOT TO SCALE

DWG NO AT-23-0

DWG NO AT-24-0



SINTERED BLANK FOR M735 TAPER SWAGE

TOLERANCE	
FRACTIONAL DIMENSIONS	± 1/32
DECIMAL DIMENSIONS	± .010
ANGULAR DIMENSIONS	± 1°
UNLESS OTHERWISE SPECIFIED	

REVISIONS

SYM.	DESCRIPTION	DATE	BY

TELEDYNE FIRTH STERLING

TITLE SINTERED BLANK

PROJ AUTH

WO No

DIVISION NASH

DRAWN BY WAM

CHECKED BY

APPROVED BY

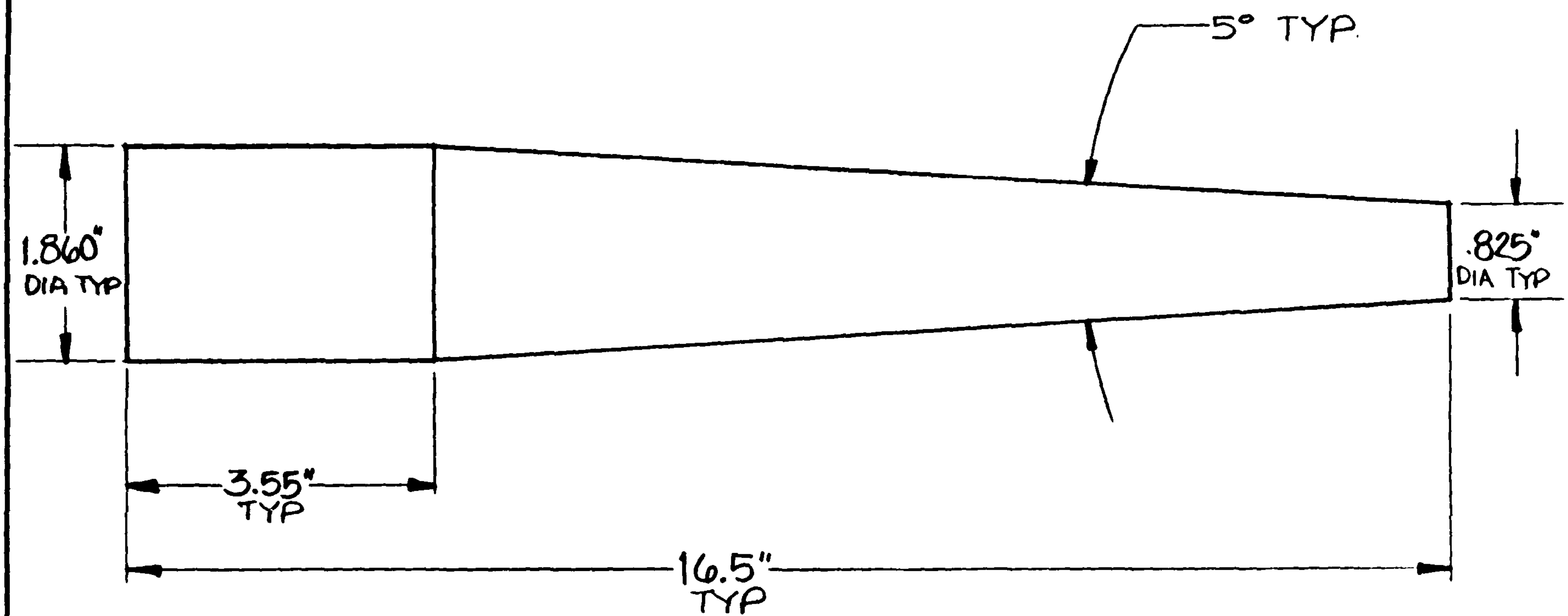
DEPT SINTERING

DATE 8-20-80

SCALE NOT TO SCALE

DWG NO AT-24-0

DWG NO. AT-25-0



PRESSED BLANK FOR M735 TAPER SWAGE

TOLERANCE	
FRACTIONAL DIMENSIONS	± 1/32
DECIMAL DIMENSIONS	± .010
ANGULAR DIMENSIONS	± 1°
UNLESS OTHERWISE SPECIFIED	

REVISIONS

SYM.	DESCRIPTION	DATE	BY

TELEDYNE FIRTH STERLING

TITLE PRESSED BLANK

PROJ AUTH
W O No

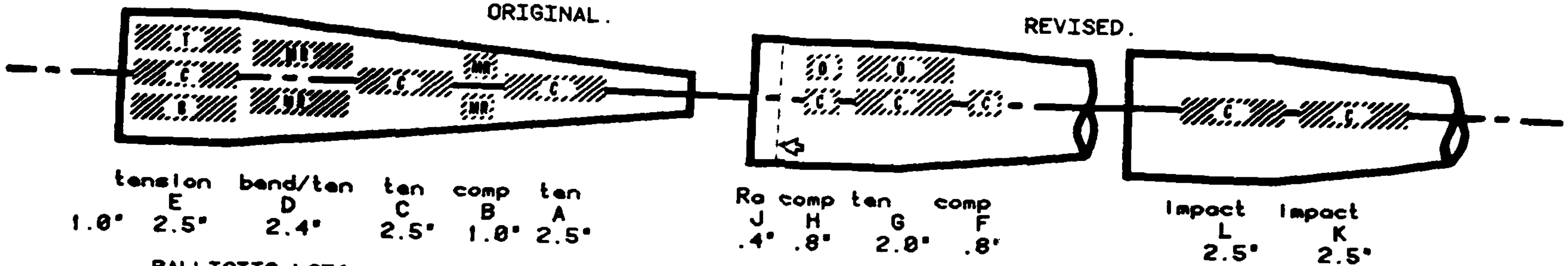
DIVISION NASH
DRAWN BY WAM
CHECKED BY
APPROVED BY

DEPT PRESSING
DATE 8-20-80
SCALE NOT TO SCALE

DWG NO AT-25-0

SUMMARY OF MECHANICAL TEST DATA

TEST COUPON LOCATION FOR TAPER SWAGE BARS

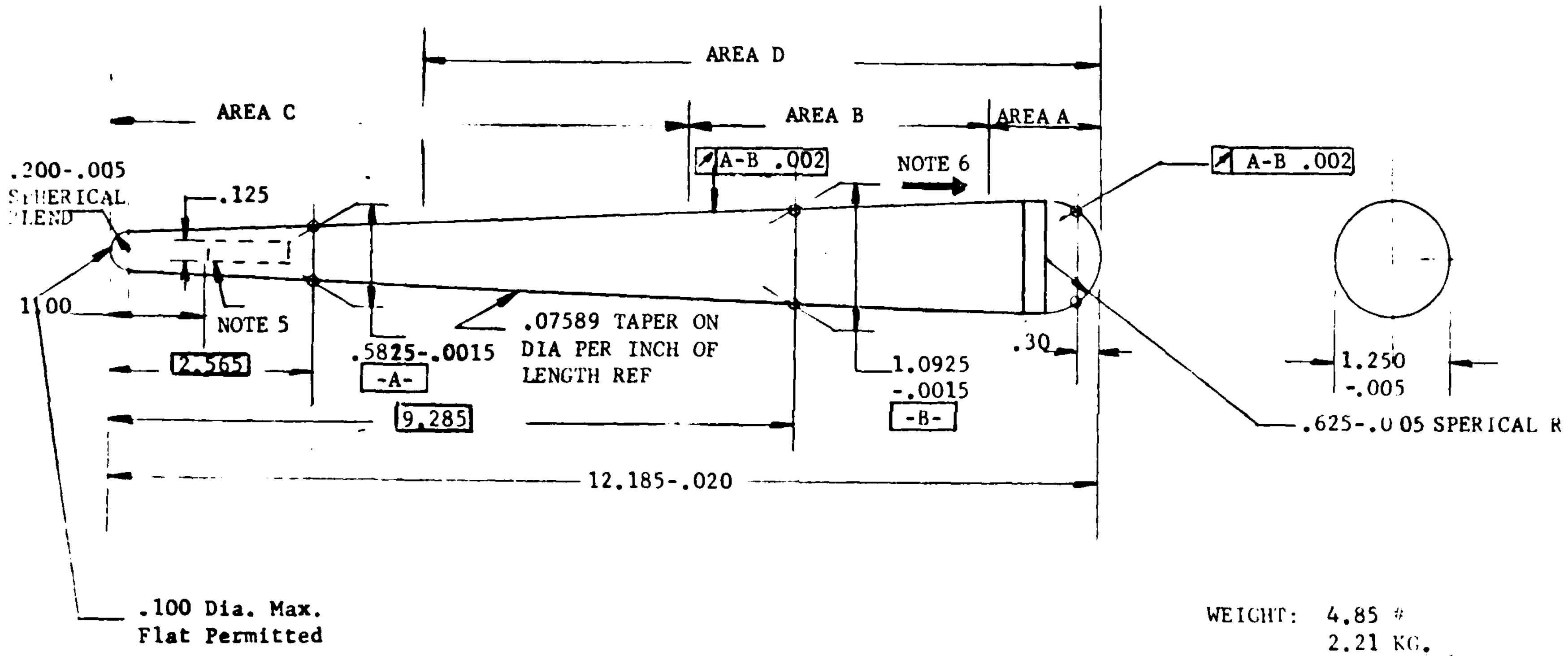


	BALLISTIC LOT#1			BALLISTIC LOT#2		BALLISTIC LOT#3		BALLISTIC LOT#4			BALLISTIC LOT#5		
IDENITY	120-A-2	120-13	120-B-3	001-327	001-365	007-001	007-018	062-016	062-006	062-003	060-024	060-026	060-030
U.T.S. K.S.I.	DMR(133.1) ET(130.0) EC(130.0) EB(131.2)	DMR 160.1 DMR 166.3	AC 128.2 DMR 171.5	AC 143.1 DMR 161.5				GC 151.6 GO 166.5					
% ELONGATION	DMR (9.0) ET (10.4) EC (5.9) EB (7.7)	DMR 2.2 DMR 1.0	AC 7.6 DMR 1.3	AC 6.3 DMR 3.0				GC 4.5 GO 1.1					
BEND STR K.S.I.		DMR 325.3											
BEND DEFL INCH		DMR .012											
COMPRESSION K.S.I.		BMR 100.0	BMR 194.7	BMR 162.0 BMR 162.4	BMR 161.2 BMR 159.9	BMR 183.3 BMR 183.5		FC 177.3 HC 175.7 HO 194.6			FC 122.6 HC 121.7 HO 176.0	FC 155.2 HC 172.3 HO 190.0	
IMPACT ENERGY Ft/Lbs			ET 6.0 EB 6.2 DMR 5.6			ET 4.0 EB 2.4	ET 4.2 EB 4.4		KC 4.5	KC 4.0	KC 5.5		KC 4.0 LC 4.5
LOAD Lbs			ET 6000 EB 7000+ DMR 5400			ET 5700 EB 4100	ET 6800 EB 5700		KC 6100	KC 5900	KC 7000		KC 5000 LC 6000
HARDNESS Ra				37.1 37.6 40.0	37.2 37.3 38.4	40.5 41.4 40.5	40.2 40.9 41.4						

( ) INDICATES TEST OF MATERIAL IN 'AS SINTERED' CONDITION.

1ST ALPHA CHARACTER AXIAL POSITION
2ND & 3RD ALPHA CHARACTERS RADIAL LOCATION

DWG NO TN 735 010



WEIGHT: 4.85 #
2.21 KG.
Surface Finish 63 All Over

(METRIC UNITS FOR INFORMATION ONLY)

TUNGSTEN ALLOY GRADE X11

TOLERANCE	
FRACTIONAL DIMENSIONS	± 1/32
DECIMAL DIMENSIONS	± .001
ANGULAR DIMENSIONS	± 1°
UNLESS OTHERWISE SPECIFIED	

REVISIONS

SYM.	DESCRIPTION	DATE	BY
	Revision 3	8/25/77	
	revision 4	4/20/78	

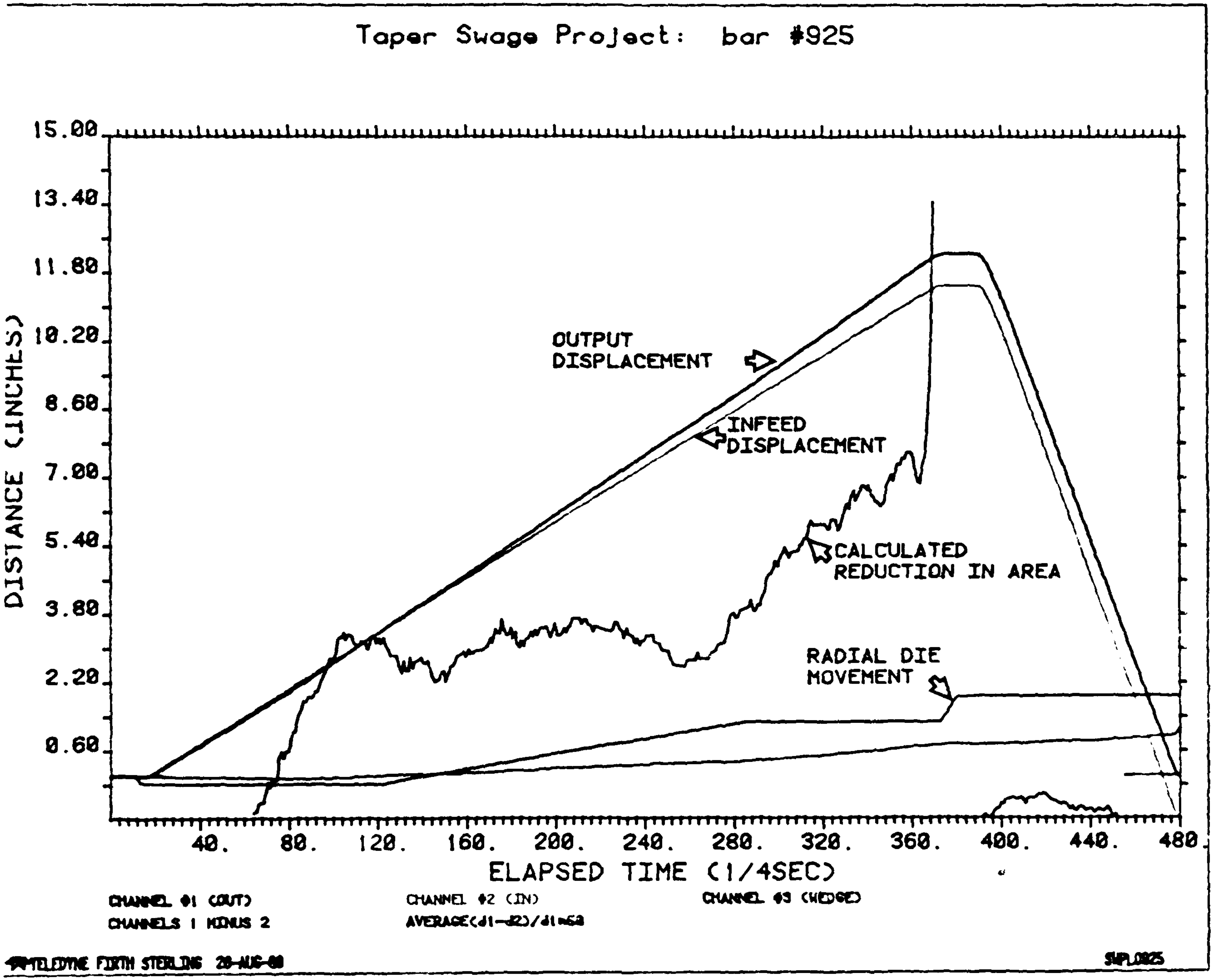
TELEDYNE FIRTH STERLING

TITLE SWACED BAR M735 MACHINE OPERATION # 8

PROJ DAAA21-77-C-0066

DIVISION Nashville
DRAWN BY
CHECKED BY
APPROVED BY
DEPT
DATE
SCALE

DWG NO TN 735-010



Taper Swage Project: bar #925
DISTANCE (INCHES)
15.00
13.40
11.80
10.20
8.60
7.00
5.40
3.80
2.20
0.60
OUTPUT DISPLACEMENT
INFEED DISPLACEMENT
CALCULATED REDUCTION IN AREA
RADIAL DIE MOVEMENT
40. 80. 120. 160. 200. 240. 280. 320. 360. 400. 440. 480.
ELAPSED TIME (1/4SEC)
CHANNEL #1 (OUT)
CHANNELS 1 MINUS 2
CHANNEL #2 (IN)
CHANNEL #3 (WEDGE)
TELEDYNE FIRTH STERLING 20-AUG-80
SWPL925

DA

FIL

6-